Interdisciplinary Research Program at MPL
Applied Research Laboratory Program 1998 Progress Report

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LONG-TERM GOAL

The long-term goals of this program are to foster interdisciplinary research efforts which combine the research interests of several investigators. In addition, the ARL Program provides partial Laboratory support for post-doctoral students and new academic appointments.

RESEARCH COMPONENTS

Ocean Sound Speed Variations in GPS-Acoustic Measurements
C. David Chadwell

The purpose of this project is to examine coherent variations of about 20 cm to 40 cm over periods of 15 minutes to tidal evident in GPS-acoustic residuals. These are likely caused by internal waves. Existing GPS-acoustic data sets are being analyzed to better understand these effects. Two goals are in mind:
(1) The possibility of exploiting these measurements as a sensor of internal waves on moored, buoy-mounted continuously operating GPS-acoustic systems that are currently being implemented by our group.
(2) Possibly improving the precision of the positioning of the seafloor points.

To date efforts have focused on isolating the oceanographic signal from systematic errors in the data and modeling by implementing several improvements to the analysis technique:

(1) Modeling of the acoustic signal propagation has been enhanced to include ray tracing through a three-dimensional sound speed structure. This is a refinement over the initial approach of a 1-D sound speed structure.
(2) The GPS processing has been enhanced to allow re-linearization of the solution to insure better convergence, improved editing to remove data outliers, better identification of phase breaks to remove their effects from the solution, and fixing of ambiguity biases to improve the positioning component. Six of the nine existing data sets have been re-processed with these new enhancements. Results are encouraging. Once the remaining three data sets have been re-processed, the GPS-acoustic derived oceanographic signals will be compared to contemporaneous CTD profiles. Final analysis and documentation should be well in hand by the end of calendar year 1998.

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Simultaneous Infrasonic Air Acoustic and Ocean Bottom Compliance Measurements
W. Crawford/G.D'Spain

This project examines the coherence between the infrasonic air acousticfield just above the ocean surface and ocean acoustic pressure field on theocean bottom in shallow water. Several natural sources (earthquakes andvolcanic eruptions, at-sea storms and hurricanes and large-scale weathersystems, comet explosions in the atmosphere, etc) as well as manmadesources (e.g., nuclear tests) create signals detectable by both types of sensors. The properties of these sources and the physics of propagation in the ocean and atmosphere are of interest, as are the natural background noise levels at infrasonic frequencies in both these media. One application of this work is in monitoring infrasound sources using seafloor measurements in areas where atmosperic measurements are impractical. The water column filters out short wavelength turbulent fluctuations that plague atmospheric infrasound measurements, and thus may provide signal-to-noise ratio gain. To accomplish these goals, an industry-standard infrasound air acoustic sensor was aquired from the French Commision for Atomic Energy (CEA). At the same time, a new-design infrasound sensor was developed and built at MPL. It is based on the very-low-noise seafloor differential pressure gauges developed at MPL and the SIO Physical Oceaography Research Division. Both infrasound sensors were put on R/P FLIP during the 25 Aug - 25 Sept experiment. Simultaneously, the seafloor pressure field and the three components of seafloor motion were measured below FLIP using two autonomous deep ocean instruments. Two weeks of data were collected successfully by the two air acoustic sensors and the two ocean bottom instruments, along with ancillary environmental and FLIP motion data. The air acoustic data presently are being transcribed into a format suitable for analysis. Initial analysis of the seafloor pressure data shows strong pressure signals in the infragravity (0.004-0.03 Hz) and microseism (0.1-1Hz) wave bands. The pressure spectra in these bands grow, decay, and shift slowly with time, presumably in response to local meteorological conditions and/or distant storms. Also, several discrete events exist in the “noise notch” between the infragravity and microseism bands. Additional performance measurements of the new-design MPL infrasonic air acoustic sensor and analytical intercomparison of the air and ocean acoustic data are planned for the near future.

The Influence of El Nino on Ocean Mixing
Robert Pinkel

All ARL support this year was devoted to preparing a high resolution Doppler Sonar and two rapid profiling CTD's for the August -September FLIP cruise. Our scientific objective is to document the scattering of the surface tide from the undersea topography and the resultant ocean mixing. This process is expected to be unusually violent at sites where the topographic slope is equal to the ray-slope of the internal tide. The ray-slope is determined by the vertical density gradient of the water at the depth of the seamount. This gradient is modulated by el Niño, with the result that sites of strong upper ocean mixing migrate between el Niño and non el Niño years. The mixing associated with the scattering process can affect the density and sound speed profiles locally. This is of relevance to those planning to install acoustic systems on seamounts. A spring-neap variation in system performance might result. The cruise was complicated by restrictions imposed by the Pacific Missile Range, which refused to clear the specific seamount initially chosen for the experiment. Using the Smith-Sandwell digital topographic data base, a second site near the Mexican border was located. It proved to be nearly ideal.

FLIP was deployed to the site and tri-moored uneventfully. The sonar and CTD's were brought up without difficulty and were operated continuously through the cruise. The CTD's profiled from top to bottom (~ 800 m at the site) every 4 minutes. Roughly 10,000 profiles were collected. The sonar, mounted on FLIP's stern, profiled from 120 to 400 m. As per expectation, extremely large currents (1kt) and isopycnal displacements (100 m) were observed around the seamount. Curiously, the strong currents and strong displacements did not happen at the same time. Hopefully, a zeroth order picture of the seamount phenominology will emerge from our initial examination of the data. Mathew Alford, a recent graduate of the Ocean Physics Group, was chief scientist. Mathew has produced an exceptional thesis and the experience of being in command at sea is a valuable addition to his education A last-minute requirement to relocate the cruise to the south was detrimental to Grant Deane's efforts to monitor breaking waves and John Hildebrand's interest in listening to blue whales. However the generally moderate weather made data collection for this project very successful.

Manipulator System: Preliminary Design (FY97)
F. N. Spiess

During the immediate past period studies have been made to define more precisely the various tasks that this development would support, as well as refining (including cost estimation) the nature of the three major components that would make up a complete system. These elements are described in more detail in a brief technical report by one of the PI’s (Hildebrand). Since this portion of the effort has been carried out by UCSD-funded personnel, there has been no cost to the project as yet. Need for this adaptation to the existing Control Vehicle arises in two ways. First, there are very few vehicles capable of carrying out manipulative tasks on the deep sea floor (to 3-6 km depth), and all those now in existence require the use of a specialized ship (e. g. Alvin, MBARI's Tiburon) or special winch systems (e. g. Canadian ROPOS, WHOI Jason). Second, all the existing systems rely on essentially neutrally buoyant vehicles, and thus have limited load handling capabilities. The report details 9 specific categories of system tasks, including recovery of ocean bottom instruments that have been buried in the sea floor or have failed/tangled release mechanisms, precision placement of seafloor instrument and their maintenance (e. g. battery replacement), and collection of heavy samples when the context must be well understood. The manipulator system would be operated below the Control Vehicle, connected by a soft tether as has been the case in other applications. The tether acts as a suspension member, with a core to carry power and telemetry. Once the package is on the sea floor the tether CV is further lowered and moved off in an appropriate direction so that the package is isolated from the ship-induced heaving motion of the CV, and the line will not interfere with the operation of the package. This approach has been used successfully in the precision placement and monitoring of recording packages in Ocean Drilling Program reentry cones in up to 5 km depth. The package itself consists of three major elements - the base, an extendible boom, and a manipulator. The base would provide stability on the sea floor, with extendible legs as in conventional on-land crane systems. The base would also house the electronic/electrical interface equipment for power conditioning and telemetry. The boom would be similar to those used on small cranes, articulated and with a telescoping jib. The manipulator (with attached TV and lights) would be mounted at the end of the boom. Cost estimates for the major components are based on existing manipulators (e. g. Schilling Orion) and small cranes, as well as our experience in building other vehicles having functions similar to those for the base unit. Approximate apportionment would be: manipulator $100k, Boom (with lights and TV) $50k, Base (electronics, hydraulic system, frame, stabilization extensions) $130k. There are two keys to the ability to operate a system of this kind without the need for exotic wires or winches. First is the fact that the package will be stabilized by placing it on the sea floor, with isolated connection through the soft tether. The second is exploitation of the fact that the necessary viewing capability for carrying out operations from a stable location in relation to a more or less stationary target (terrain to be sampled, inert objects to be placed or picked up) can be carried out with a narrow band, slow scan TV of the type that we use in other situations (e. g. wireline reentry CV) in which the primary cable is

0.68" coax-cored logging cable, available on most of the mid and large size UNOLS ships. The principal task remaining is the detailing of the base structure (including the stabilizing extension legs, selection of hydraulic system components) and design of the electrical/electronic aspects.

Noise Impact on Blue Whales
J. Hildebrand

The goal of this project is to study the impact of low frequency noise on blue whales -- relevant to issues of environmental compliance for the Navy. Blue whales, the largest mammals on earth, are an endangered species. They produce loud low frequency (20 Hz) acoustic calls, presumed to be for communication and/or to sense their environment. The Marine Mammals Protection Act and the Endangered Species Act are laws which are designed to provide blue whales, and other marine mammals, with protection from excessive sound exposure which might be injurious to their hearing or disruptive to other behaviors. A key question is what level of underwater sound exposure is appropriate for regulation. Current standards for marine mammal sound exposure are poorly documented because of the difficulty in monitoring underwater effects of sound exposure. Our proposal is to develop acoustic techniques for monitoring both underwater sound exposure and the vocal behavior associated with exposure for blue whales. In particular, we are developing a system for recording and rapidly analyzing array of fixed or floating sonobuoys to detect and localize blue whale calls, as well as environmental noise sources, such as nearby ships. With ARL support we conducted a field program to record blue whale calls in the California continental borderlands to study the impact of low frequency noise on these calls. The continental borderlands near shore is the site of extensive shipping, a source of low frequency noise. Using sonobuoys, many blue whale calls and associated noise from shipping was recorded near the Channel Islands National Marine Sanctuary. Typical blue whale calls are low frequency tones with fundamental frequencies near 20 Hz. The Channel Islands recordings from this summer showed an unusually large number of short-duration downswept-frequency calls, relative to the more typical tonal type calls. We suggest that these calls may be related to near-by ranging by the blue whales, in analogy to chirped sonar. We recorded several instances where a blue whale could be identified both from visual observations and from acoustic recordings of vocalizations, with good correspondence in localization. Analysis continues on the impact of low frequency noise from ships and other sources on the character of these calls.

Long Time-scale Ambient Noise Measurements in the Surf Zone
Grant Deane

To develop an empirical model for surf noise by recording ambient noise over the band 50Hz to 20kHz, wave height and wind speed in very shallow water over a 12 month period. An autonomous data collection system has been built and deployed in 8m of water, 200m southwest of Scripps Pier, La Jolla and approximately 200m from the surf line. The surf monitoring array consisted of 4 broad-band hydrophones and a pressure sensor which recorded ambient noise and wave height for 9 minutes every hour from July 1997 to mid June, 1998. The noise recordings exceed 1.5 Terra bytes of data and provide data through a wide range of incident wave fields and weather conditions, including several winter storms. Each of the 9 minute segments in the data set (there are roughly 7500 of them) have been analyzed into 6 octave bands covering the frequency band 32Hz to 1024Hz. The sound of snapping shrimp dominates the ambient noise spectrum above about 2000Hz, effectively providing an upper limit for the surf noise analysis. Of the 7500 noise segments, approximately 1200 have been identified, by manual inspection of ambient noise spectrograms, to be dominated by surf noise. The octave band averages from the 1200 surf-dominated data segments have been cross correlated against the measured environmental conditions, which included the RMS height and dominant frequency of the incident surface wave field, the wind speed and direction and the mean water depth, which varied with the tidal cycle. The correlation analysis shows that the single most important predictor of surf noise level is the RMS height of the incident wave field and that the noise level is proportional to the square of the RMS wave height. A secondary predictor of the surf noise level is the mean water depth which varies with the tidal cycle. This is presumably because the range between the noise monitoring station and the line of breaking surf also varies with the tidal cycle. There is also an additive noise component noticeable when the wind exceeds 7m/s and white-caps start to form. The most important conclusion to arise from this study is the discovery that surf noise level scales with the square of RMS wave height. There is a simple physical interpretation of this result. The available mechanical energy in the incident wave field per unit cross-sectional area of ocean surface is proportional to the RMS wave height squared. Since the surf noise level is also proportional to RMS wave height squared we can conclude that the percentage of mechanical energy converted to acoustic noise is, to first order, constant.

PUBLICATIONS

Deane, G.B., Long time-base measurements of surf noise, J. Acoust. Soc. Am., 104, p.1838 (Abstract) 1998

Optical Laser Measurements of Micron-sized Bubbles in the Surf Zone Grant Deane

The original objective was to develop an underwater imaging system to photograph bubbles in the size range10-100 microns radius in the surf zone. Field trials with a prototype resulted in changing the bubble size target range to 100-10,000 microns radius. The long term objective is to improve the understanding of the wind-generated component of oceanic ambient noise by studying the formation of bubble plumes beneath breaking waves in the open ocean. An underwater optical imaging system (Bubblecam) has been developed that provides qualitative and quantitative data on the bubble size distribution and bubble formation mechanisms in the plumes of bubbles that form directly beneath breaking waves. The difficulty with making measurements inside dense mixtures of air and water that form bubble plumes is the strong scattering of light and sound that occurs at the plume boundaries. The instrument developed under this program overcomes this difficulty by maintaining an optically clear path between the imaging optics and the volume of bubbly water under study. Placing the instrument in the interior of the bubble plume allows the creation of images which yield the bubble size spectra and give an indication of the spatial distribution of bubbles during plume formation. The instrument operates by creating a high intensity sheet of light, approximately 3.5mm thick and 37mm wide, a few millimeters in front of an optical face plate. Any air cavities inside the illuminated volume scatter lithe out of the sheet and through the face plate. Images are formed and recorded by focussing the scattered light through a borescope and onto a video camera. The instrument has been successfully deployed once in the surf zone and twice in the open ocean.

PUBLICATIONS

Stokes, M.D. and Deane, G.B., A new optical instrument for the study of bubbles at high void fractions within breaking waves, submitted to IEEE, Journal of Oceanic Engineering.

Deane, G.B. and Stokes, M.D., Air entrainment processes and bubble size distributions in the surf zone, Journal of Physical Oceanography, In press, 1998

A Study of the Bubble Size Distribution Beneath Breaking Waves in the Open Ocean
Grant Deane

OBJECTIVE

To measure the bubble size distribution and its evolution in time in the high void fraction plumes generated beneath breaking waves in the open ocean.

PROGRESS

An optical instrument to measure bubble size distributions in high void fraction plumes generated beneath breaking waves (Bubblecam) was deployed from the research platform Flip, 100 miles southwest of San Diego, California in August of this year (1998). The instrument was mounted on a surface following frame and tethered to a boom deployed over the side of Flip. Video recordings of the ocean's surface, wind speed and direction, Flip's heading and surface wave elevation measurements were made simultaneously with the measurements from Bubblecam. Weather conditions were calm during most of the 4 week deployment, and only one day ahs sufficiently high wind speeds to generate white caps and permit data collection. However, approximately 50 breaking waves events occurring over Bubblecam were recorded. A preliminary examination of this data set indicates that high-quality optical images were obtained that will, when analyzed, yield bubble size distributions within wave induced bubble plumes and a qualitative study of bubble formation mechanisms within waves.